Simple and Effective Method for Improving Performance and Resiliency of GNSS Time Transfer

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Agenda

- Introduction – GNSS PRTC-B and jamming incidents (STRIKE3 report).
- Jamming test setup.
- Performance of GNSS PRTC-B receivers throughout jamming.
- Server-client architecture for GNSS receivers.
- Real-Time Common View Time Transfer
- Summary

Introduction – PRTC-B and jamming incidents

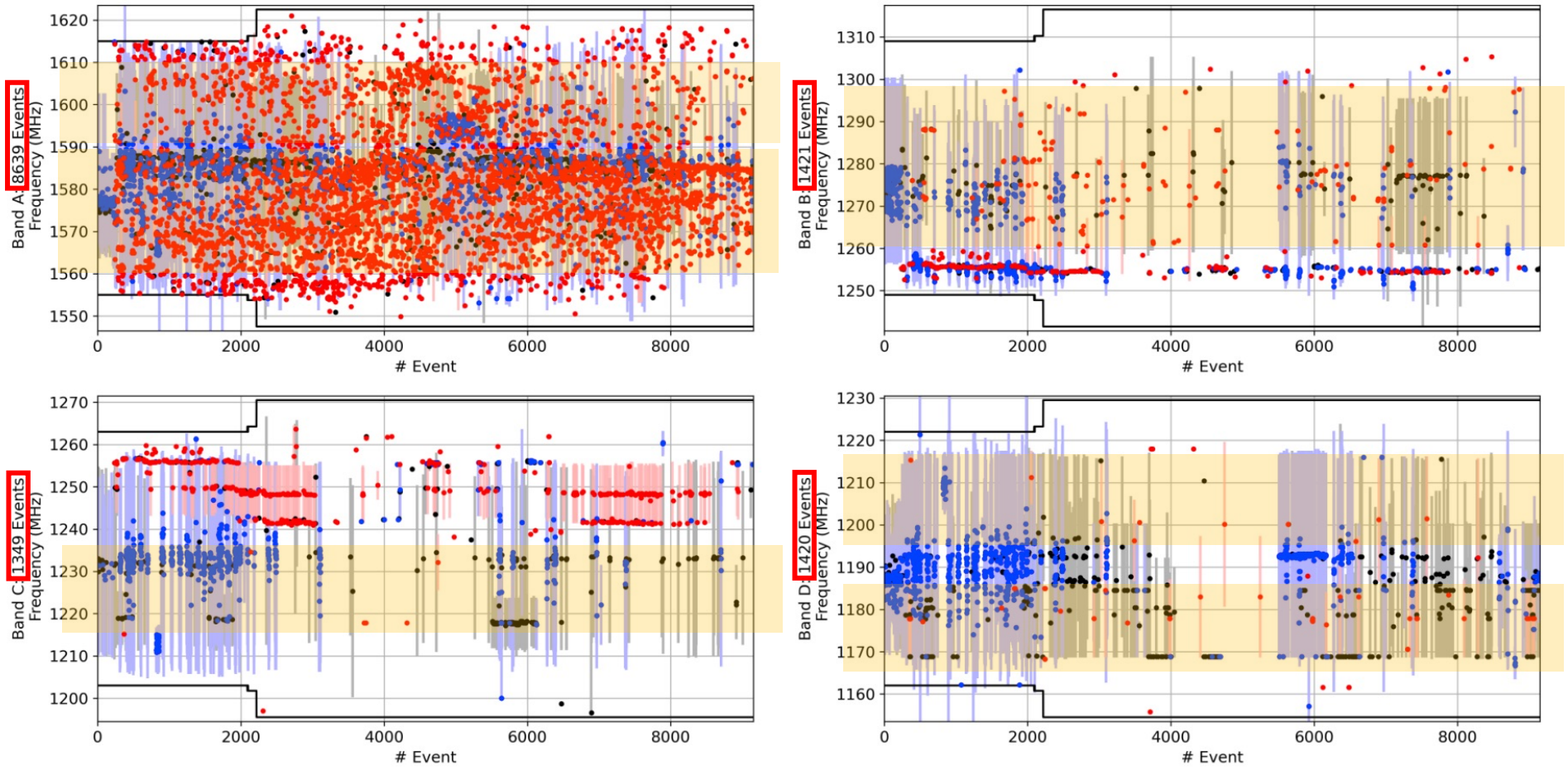
- STRIKE3 report (2017-2018) observed **upward trend** in the number of reported events throughout the campaign.
- Variation in interference events is very large across sites.
- Note that with proliferation of personal GNSS devices we could expect proliferation of personal jamming devices.

Site number	Monthly avg. no. chirps	Infra-structure	Local environment	Distance to minor road	Distance to major road
16	5227.800646	Airport	City centre	-	45 metres
15	1298.975261	Office	City centre	-	4 metres
17	799.3028203	Office	City centre	-	40 metres
18	742.3686946	Airport	Airport	300 metres	4.5 km
19	433.9995226	Airport	Airport	500 metres	4 km
47	421.3333333	Airport	Inter-city motorway	-	80 metres
10	252.1503831	Office	City centre	29 metres	260 metres
13	220.7717622	Office	City centre	65 metres	178 metres
12	117.4520601	Office	City motorway	30 metres	150 metres
42	55.42857143	Power Grid	City motorway	-	200 metres
5	53.5577328	Airport	City motorway	-	119 metres
31	42.69451162	Office	City centre	70 metres	250 metres

STRIKE3 Threat Database Analysis Report, Table 4-1: Site information ordered by monthly average intentional activity.

Jamming events measured at one site

- Narrowband events are indicated with red, wideband black and time-modulated blue.
- **L1 is being 6 times more often jammed compared to L2 or L5 bands.**



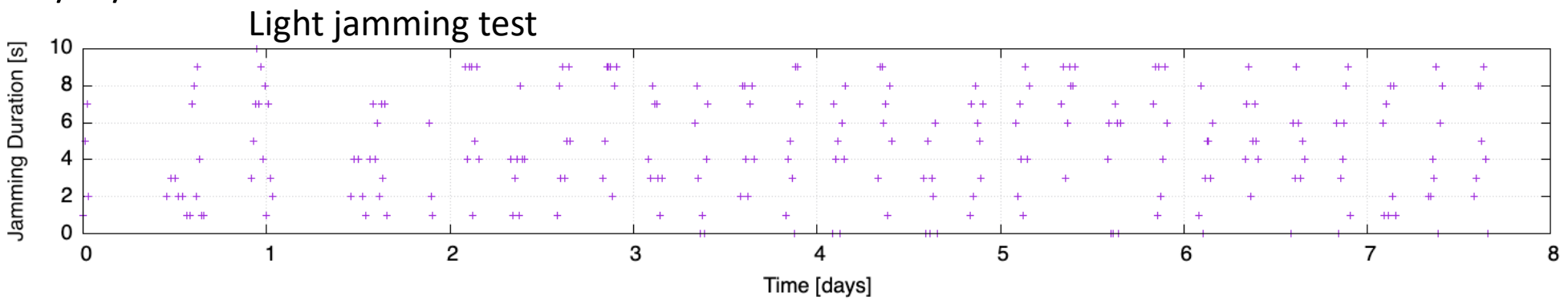
Source: https://www.unoosa.org/documents/pdf/psa/activities/2023/GNSS2023/GNSS2023_07_01.pdf

Short term jamming events

- Short term jamming events are highly likely anywhere near busy roads during peak hours (see STRIKE report).
- When you ask your PRTC-B equipment provider if their device can withstand short term jamming events, they will tell you that local oscillator, even OCXO, can handle 1 minute jamming without impacting PRTC-B performance.
- Since L1 is (un)intentionally jammed six times more often than L2 or L5, let’s find out how it affects long term stability of a GNSS receiver.

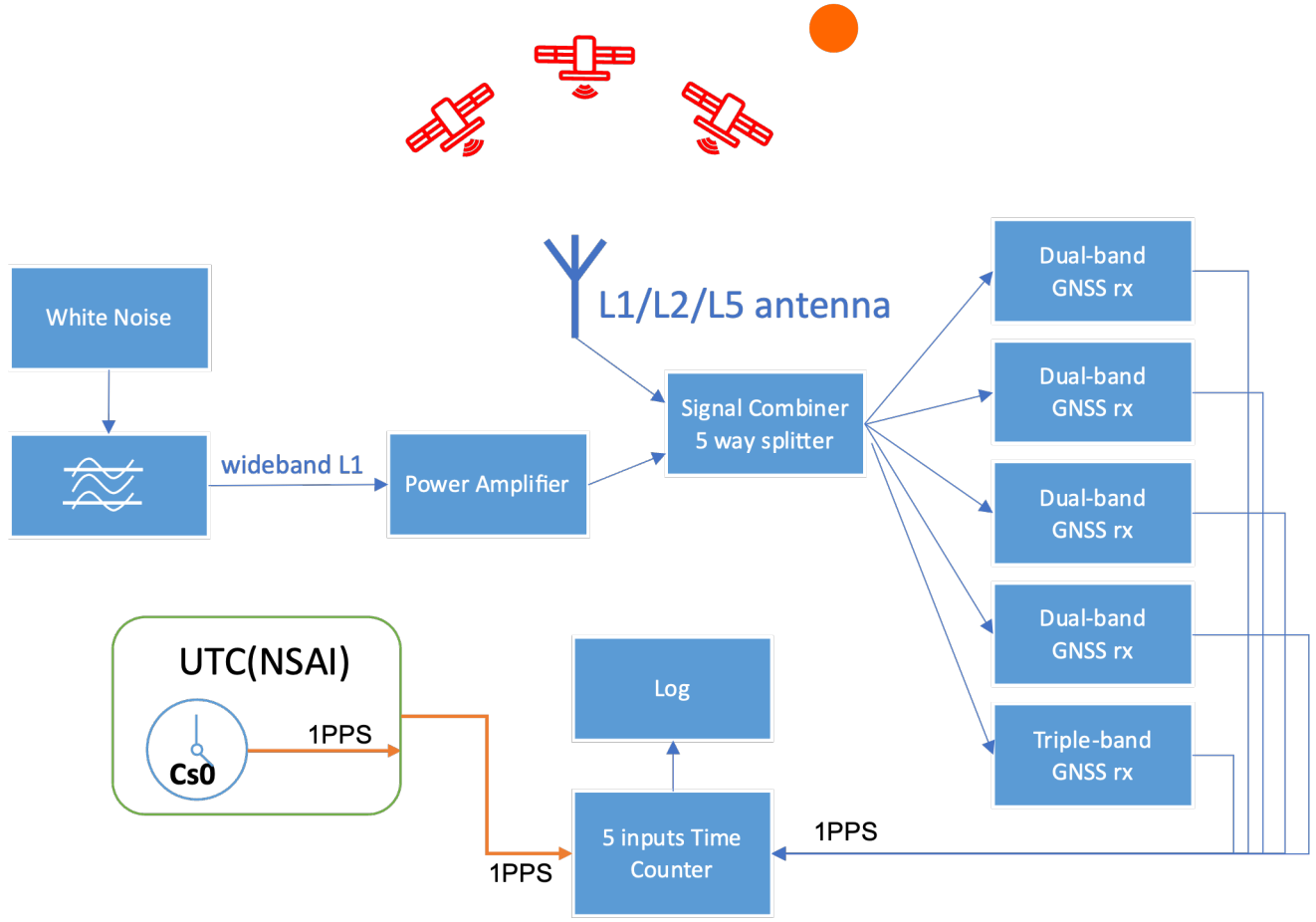
Jamming test setup – events description

- We have designed two jamming tests, and a baseline test.
- Baseline: no jamming, ideal open sky performance.
- Light test: L1 is being jammed in sessions spaced by 6 hours. In one session lasting one hour the receiver is, on average, jammed for 0.1s to 10s four times, i.e., every 15 minutes.
- Hard test: L1 is being jammed for 20 minutes 4 times a day.
- 5 receivers in total, 4 different makers (covering at least 90% of the market), L1/L5, and L1/L2/L5.



Jamming test setup – hardware

- Testing setup at NSAI NML in Dublin, reference is Cs atomic clock steered to UTC – UTC(NSAI).
- Jamming is performed by transmitting high power white noise filtered into the L1 band (1545 MHz). The signal is quite wide-band, affecting also L2 band (CN0 level degradation by about 3~6dB).

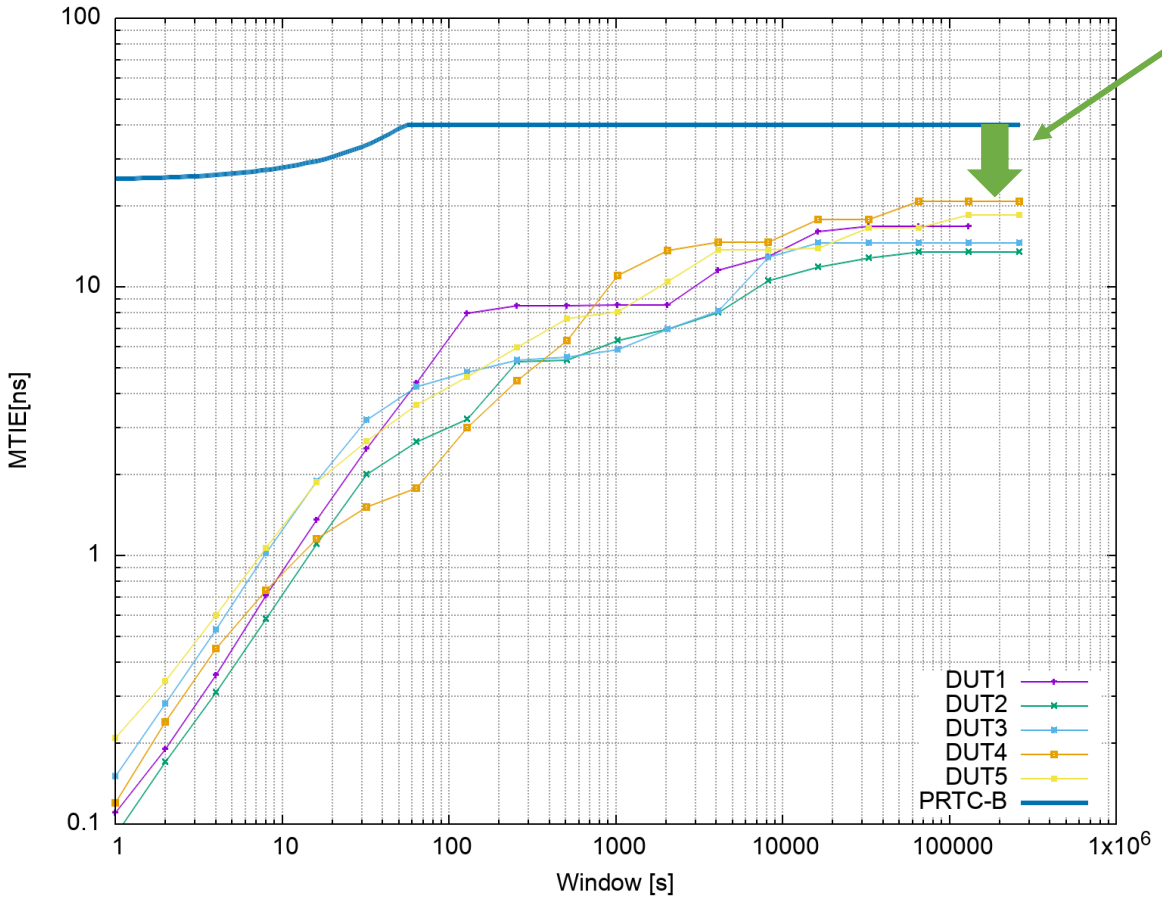


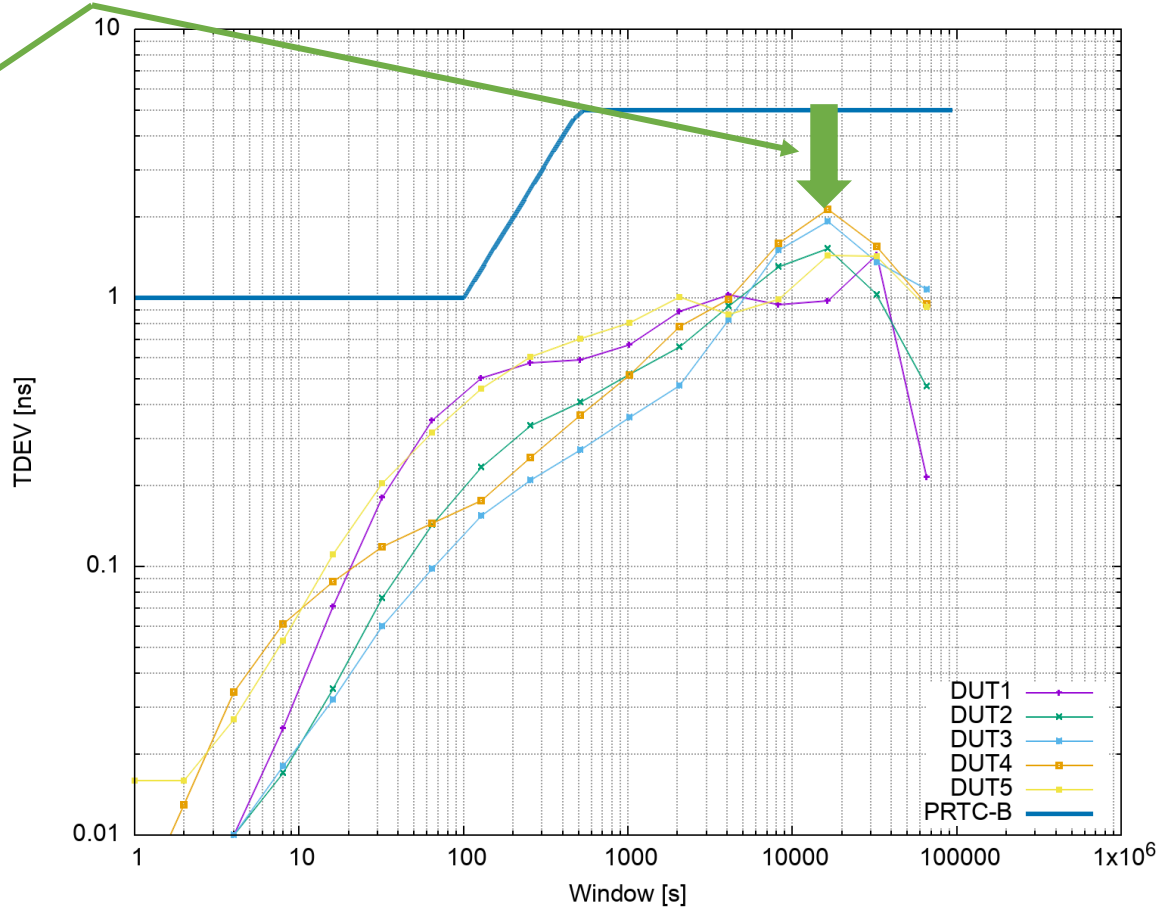
Jamming test setup – postprocessing

- PRTCs are using Phase Locked Loops (PLLs) to clean up GNSS 1PPS output signal using local oscillator (OCXO or better).
- Since L1 jamming can introduce significant phase jumps, and given the above, we postprocessed/filtered the data to emulate a phase locked loop with OCXO and a perfect holdover capability.
- Postprocessing steps for time error measurements:
  - TE aligned to rapid UTC.
  - Best possible performance evaluated (removing receiver's quantization error, if possible).
  - EWMA filter applied, representing PLL with bandwidth narrower than 8mHz.
  - At the start of the jamming the time error is frozen in a "perfect holdover". At the end of the jamming event there is a cool-off period for two minutes to let the receiver recover.

Results – baseline performance

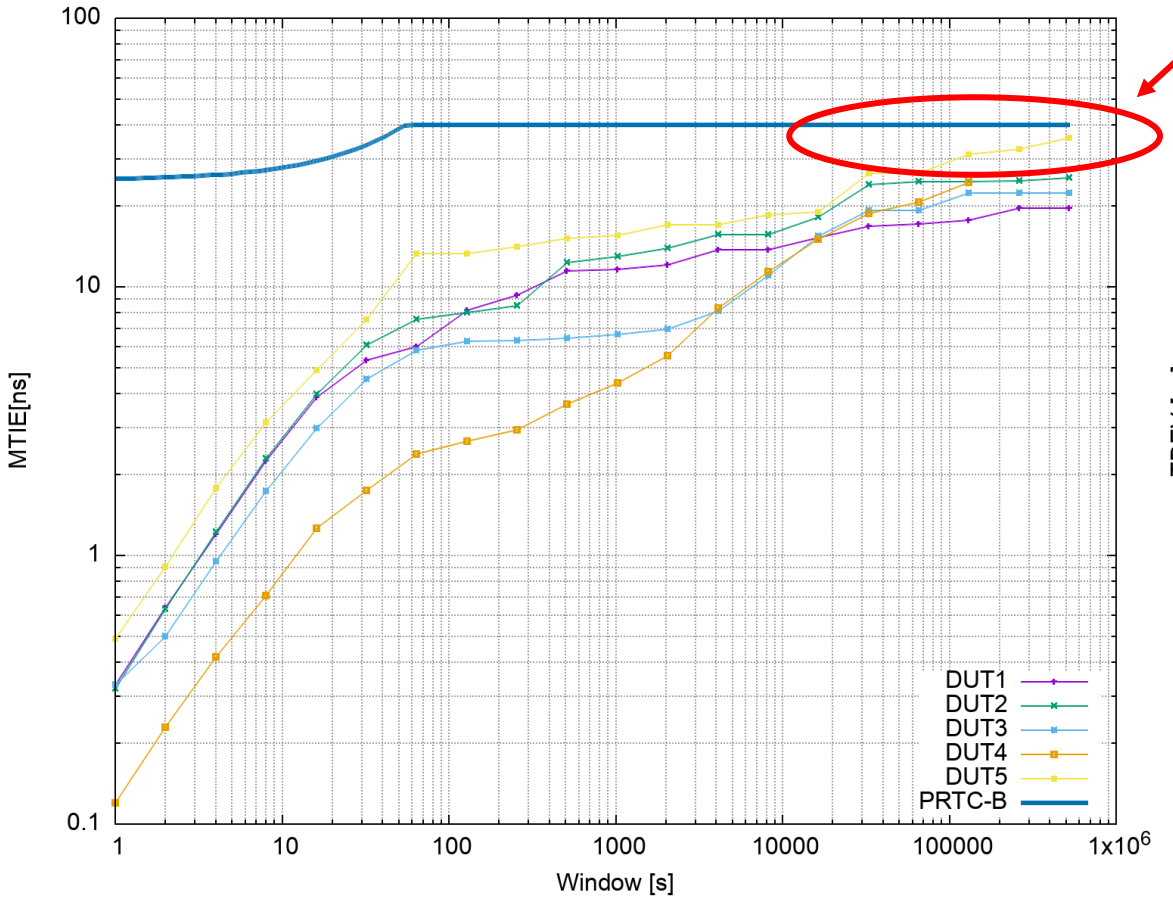
Enough margin for PLL and other components

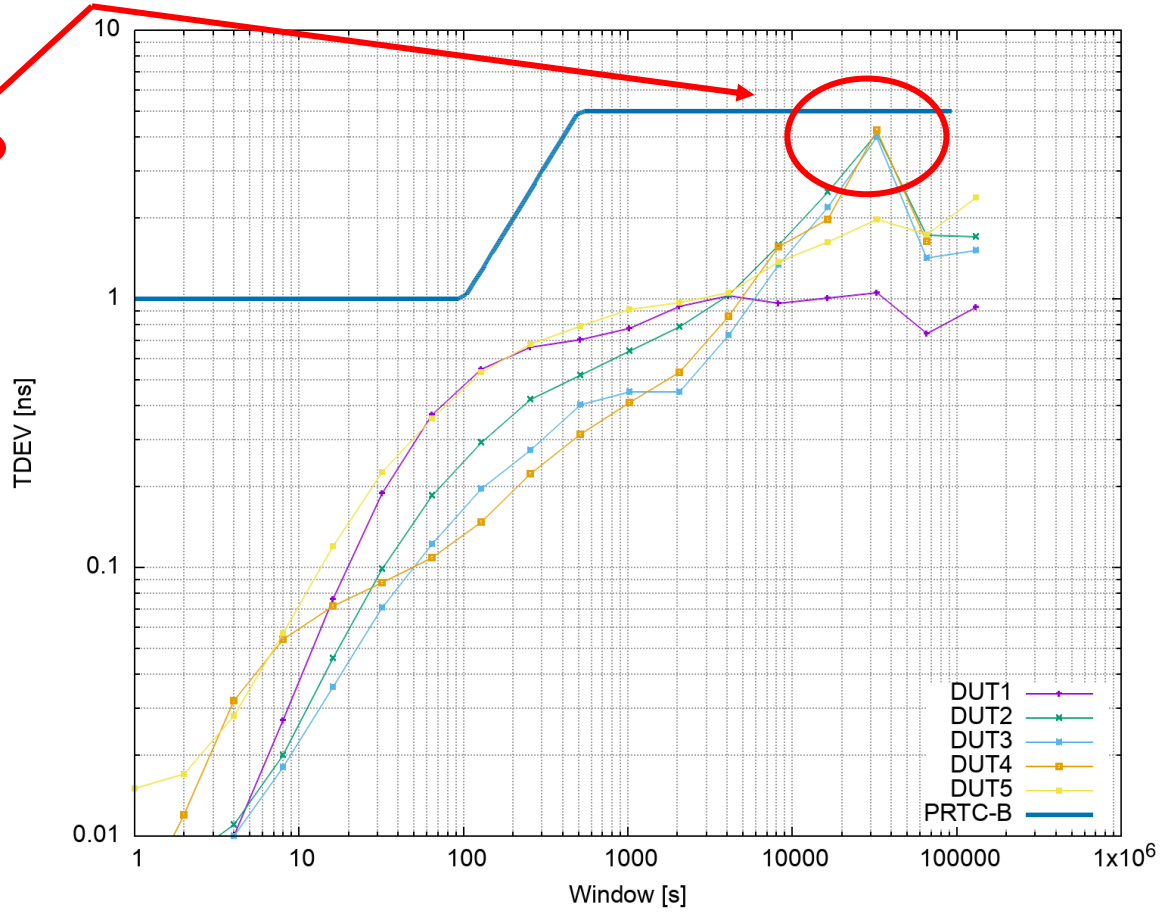




Results – light jamming test

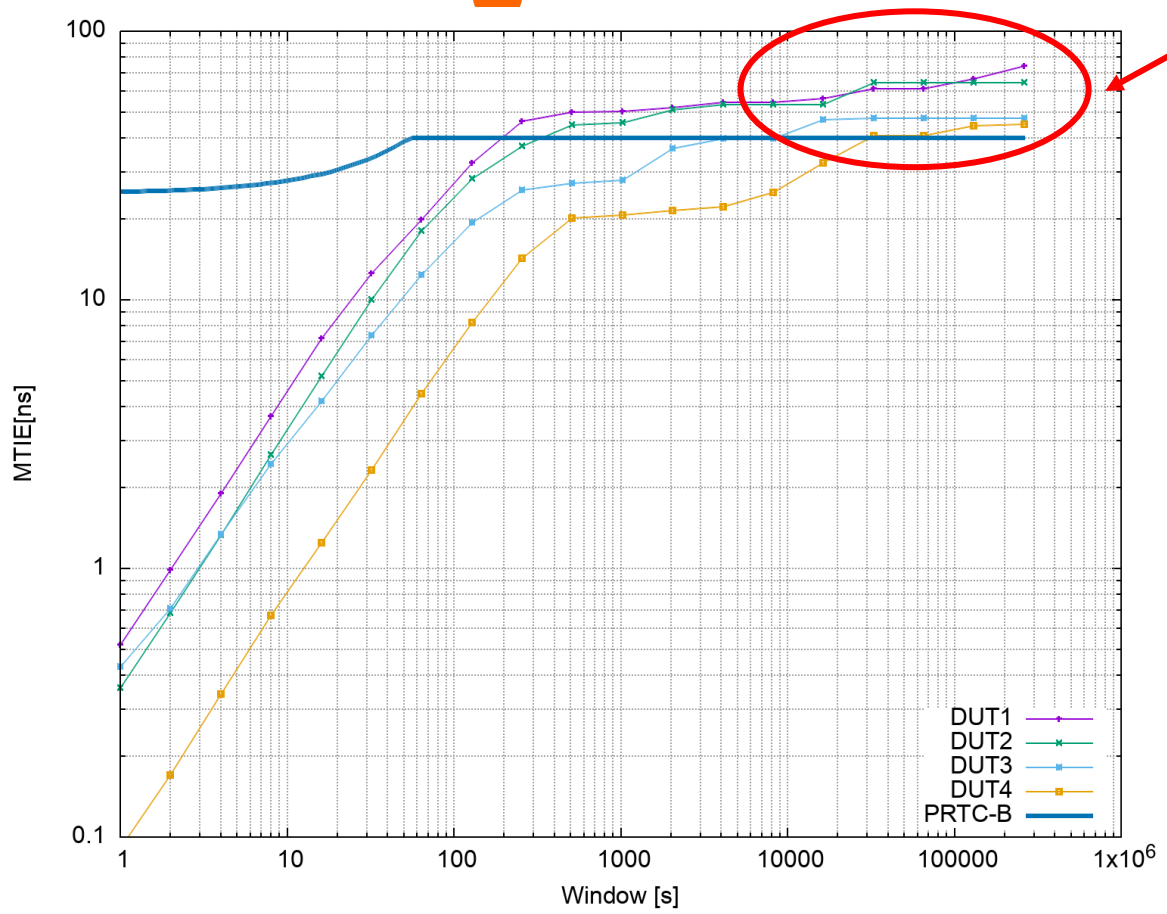
Little margin left for PLL and other components

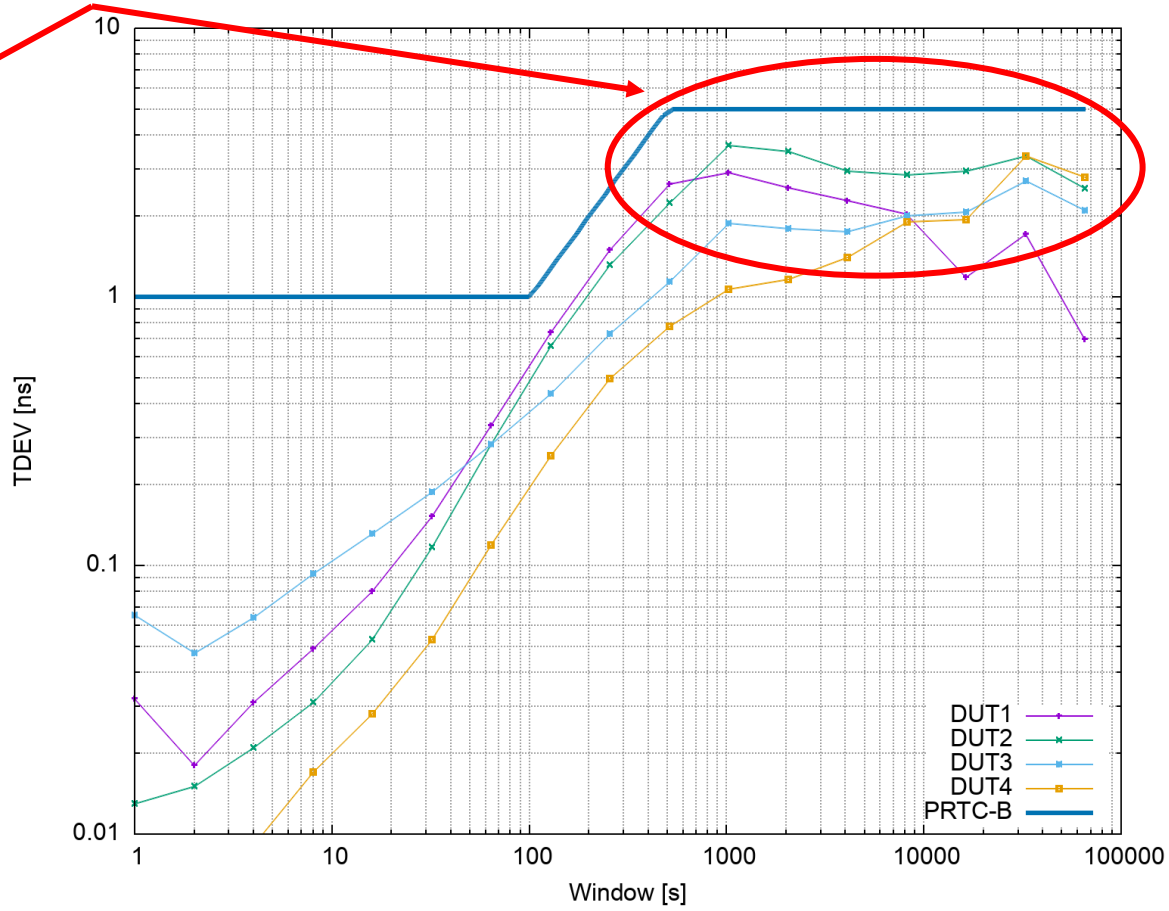




Results – hard jamming test

NOT enough margin for PLL and other components



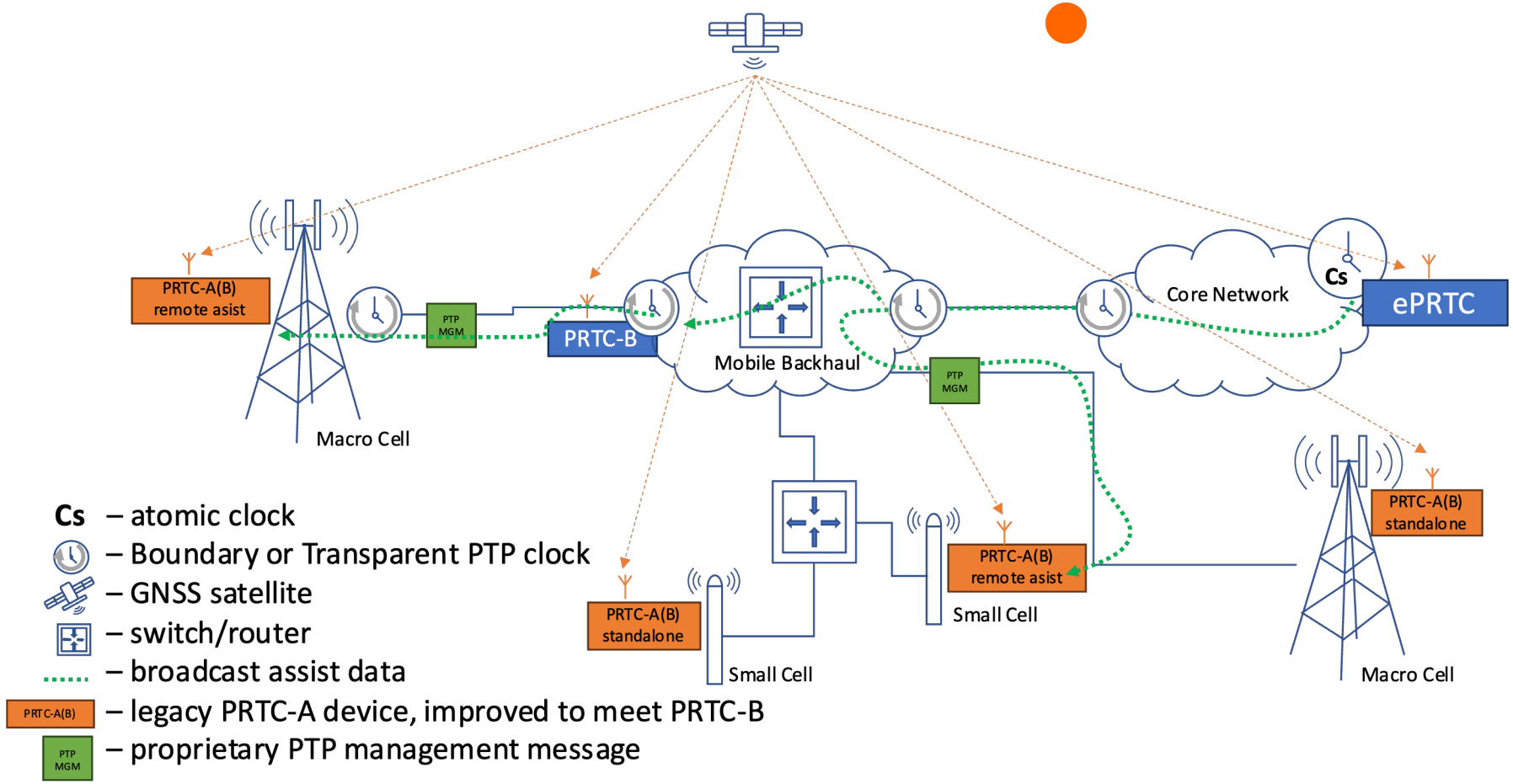


Results summary

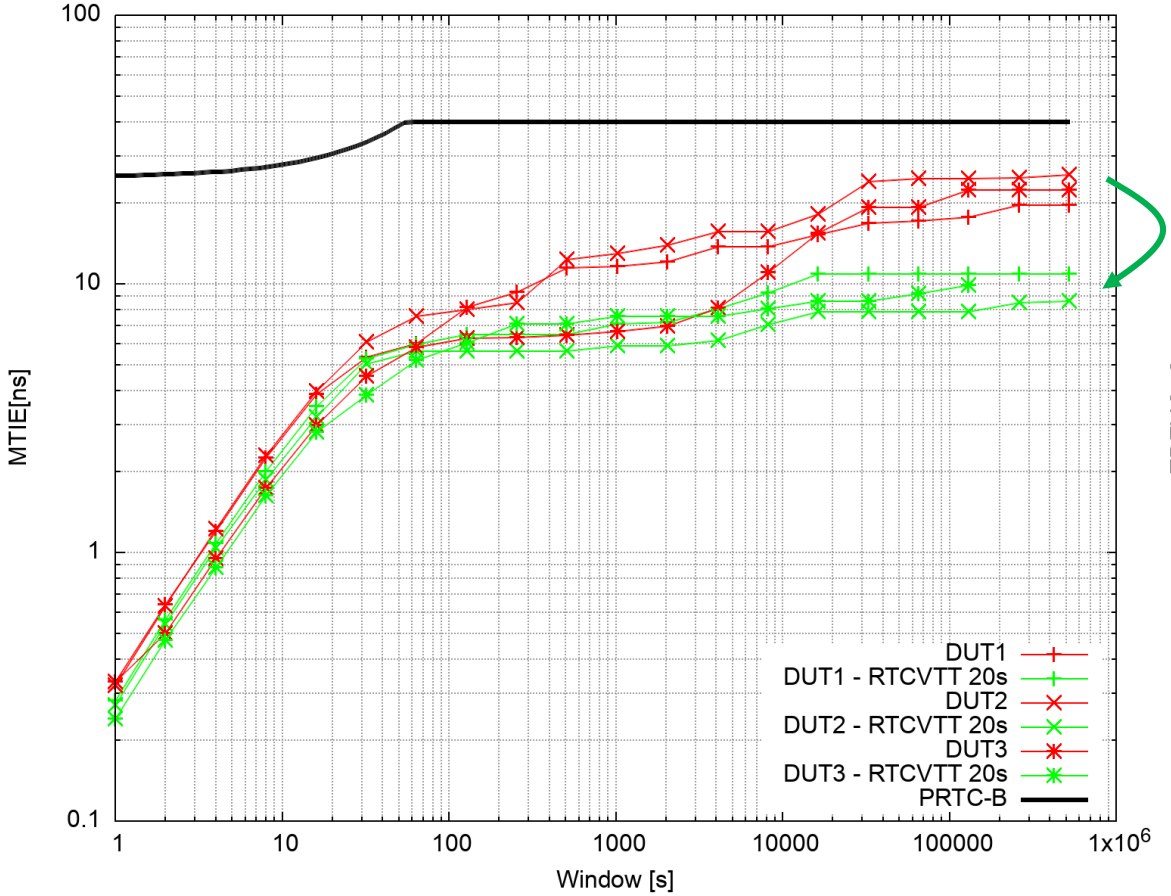
- No clear winner!
- **Light jamming test:** some degradation in terms of MTIE, or TDEV (or both) for all but one receivers.
- **Hard jamming test:** all receivers no longer meeting PRTC-B performance in terms of MTIE and no margin left in terms of TDEV metrics.
- Is there a **simple** and **cost-effective solution** that would allow to maintain **PRTC-B performance** throughout **jamming incidents?**
- Something that could be deployed immediately, through a software update, without any hardware modifications?

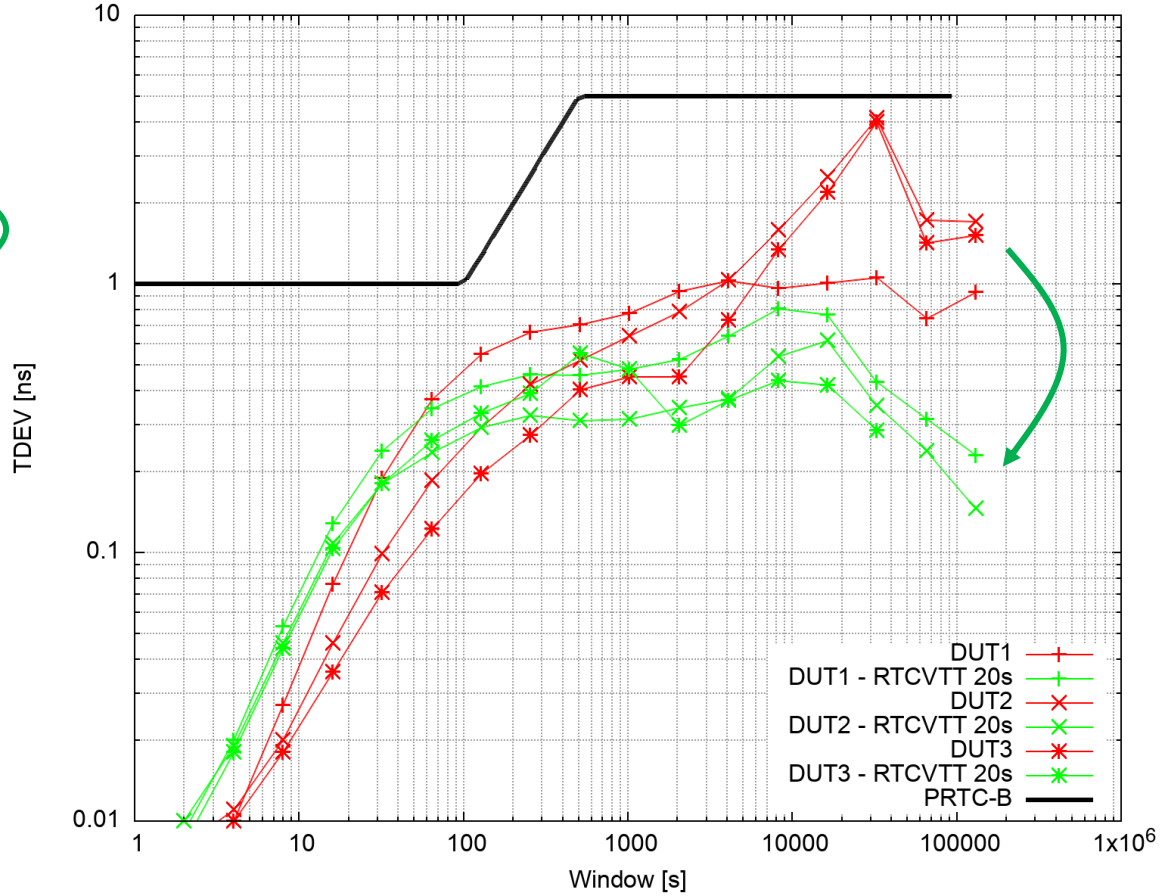
Real-Time Common View Time Transfer

- Can we improve resiliency by using a reference PTP clock (PRTC-B or ePRTC GM) and its GNSS data?
- PTP based GNSS data distribution to client GNSS devices (PRTC-A, PRTC-B or ePRTC)

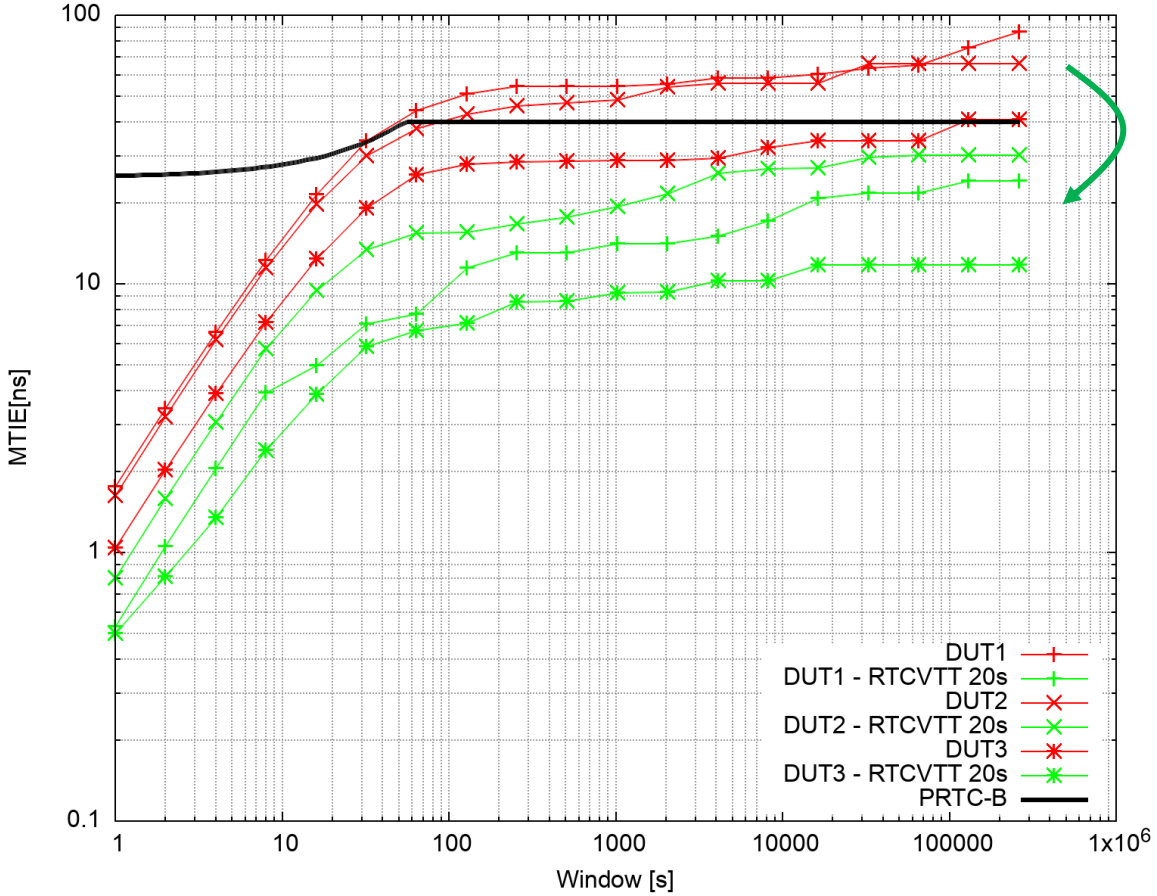


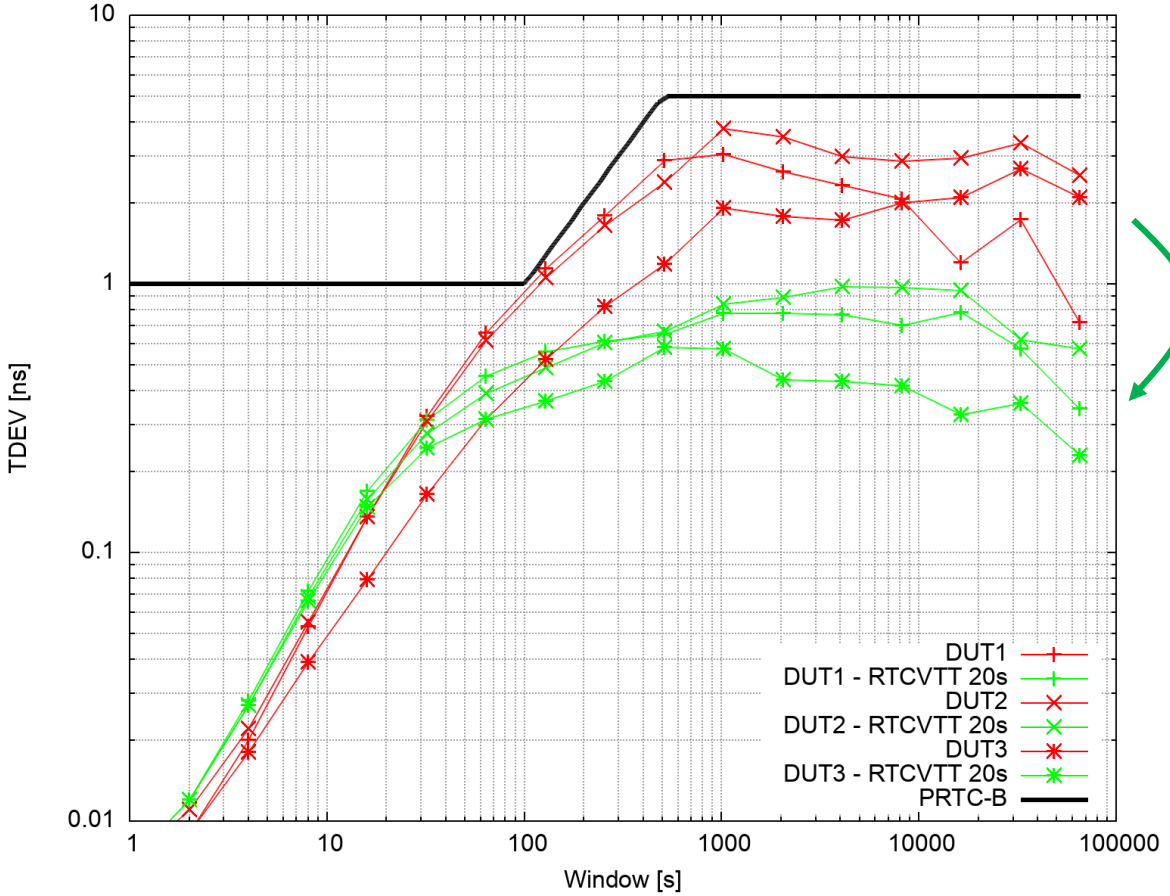
Real-Time Common View Time Transfer – Light Jamming





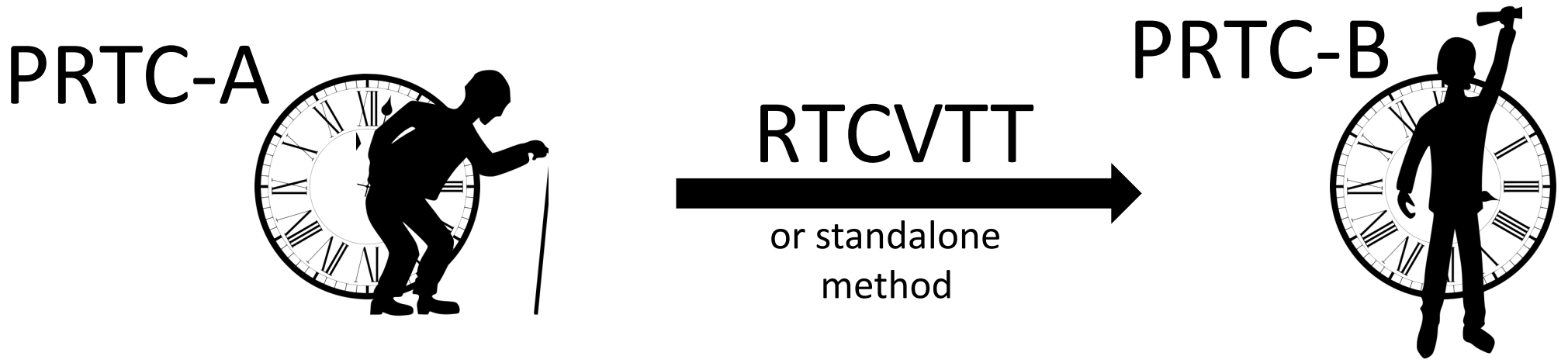
Real-Time Common View Time Transfer – hard jamming





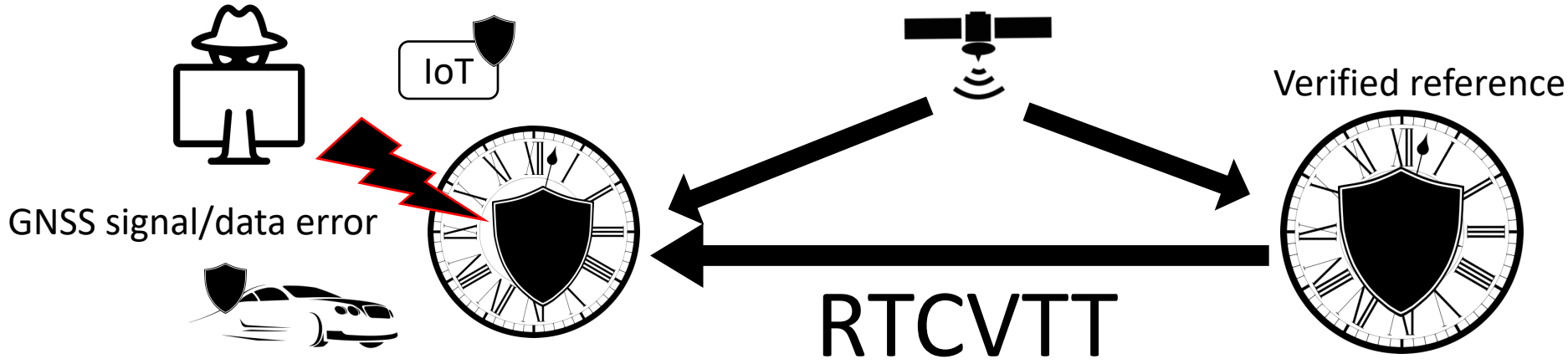
Immediate benefits of Real-Time Common View

- Maintain **at least PRTC-B** performance **throughout jamming** incidents; if you have a PRTC-B near a busy road, better be ready for interference.
- As a side effect this means that you can improve **single band GNSS devices** (legacy **PRTC-A**) to meet at least **PRTC-B**, with a simple **SW update**.
- Note that **legacy PRTC-A** can be upgraded to meet **PRTC-B requirements** with a simple software update even **without RTCVTT** (let me know if you're interested to know more)!



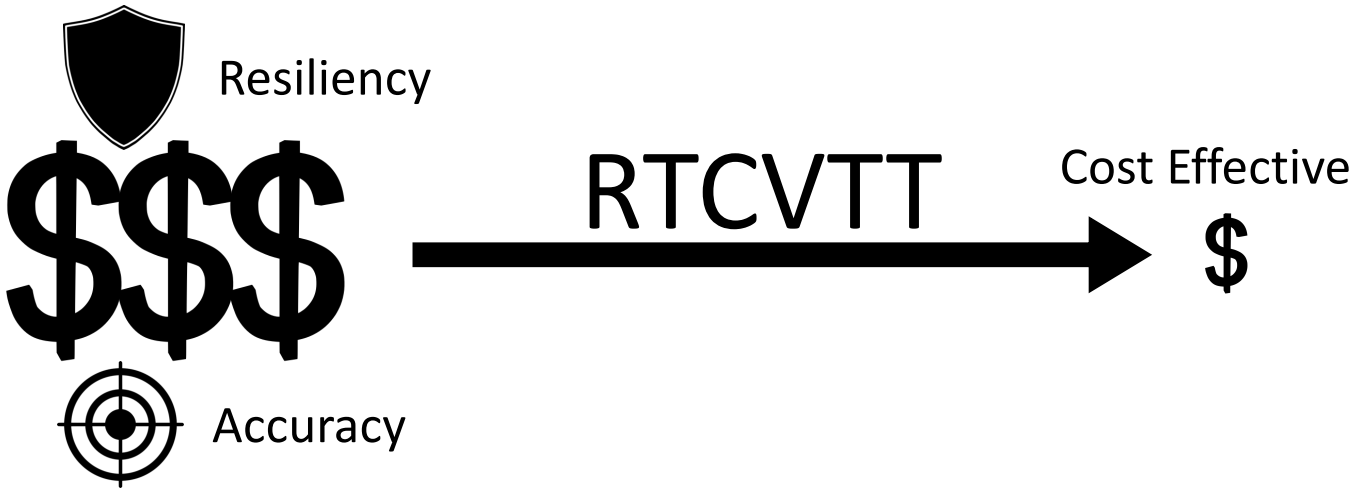
Immediate benefits of Real-Time Common View

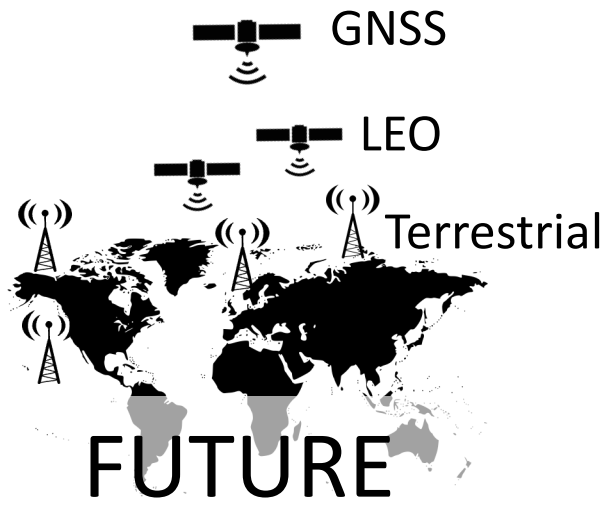
- Improve **resiliency by using verified reference GNSS data** for **any constellation** and any receiver **without the need for OSNMA** (more on that at ITSF 2024).
- **Remove** most **GNSS data** related **threats/issues**, e.g., RTCVTT would **NOT be affected** by GPS' January 2016 anomaly, nor Galileo's week-long outage;
- Detect **GNSS spoofing**: simulators & data replays.
- M**onetize** verified reference GNSS data for **automotive**, IoT, and other segments.



Immediate benefits of Real-Time Common View

- Cheap technology for enabling **coherent network PRTCs** (cnPRTCs) and **monitor ePRTCs**.
- No **monthly fees**, no external data required, everything internalized within customer's private network.
- RTCVTT is a general method, so it will be applied to other common signals in view: Low Earth Orbit satellites (e.g., Iridium STL), terrestrial signals, etc.



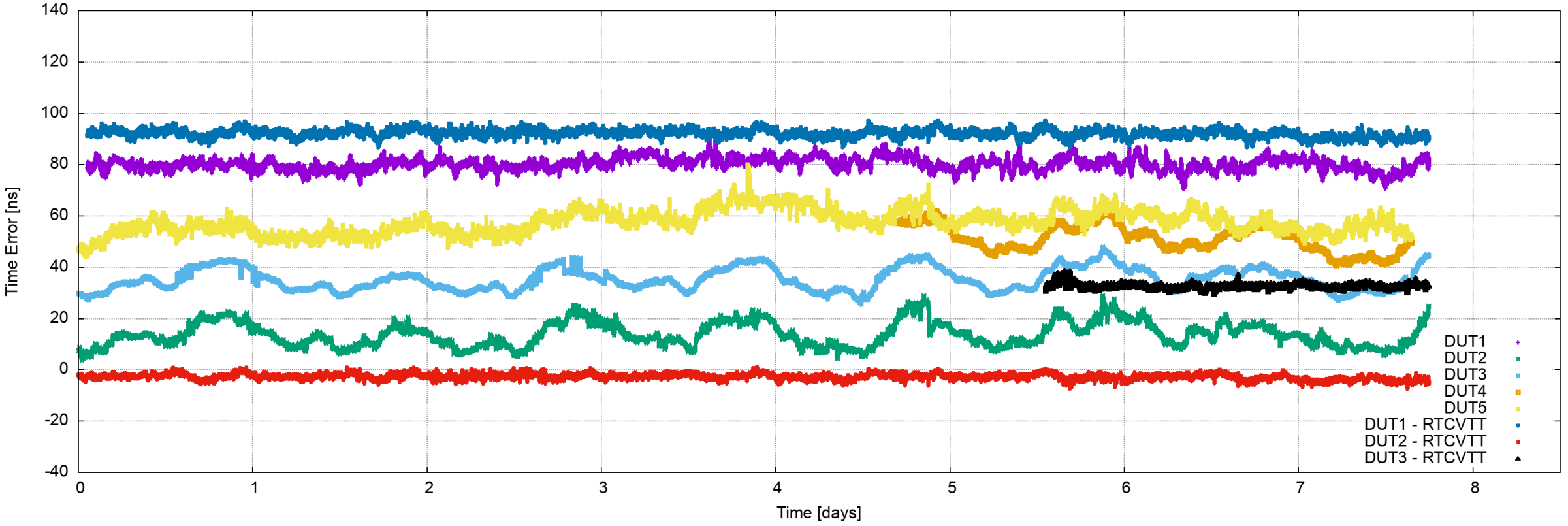


RTCVTT is the **next big thing** as it improves both, GNSS timing resiliency and performance, cost efficiently.

Thank you for your attention!

Backup slides

Time error for light jamming test case



Time error for hard jamming test case